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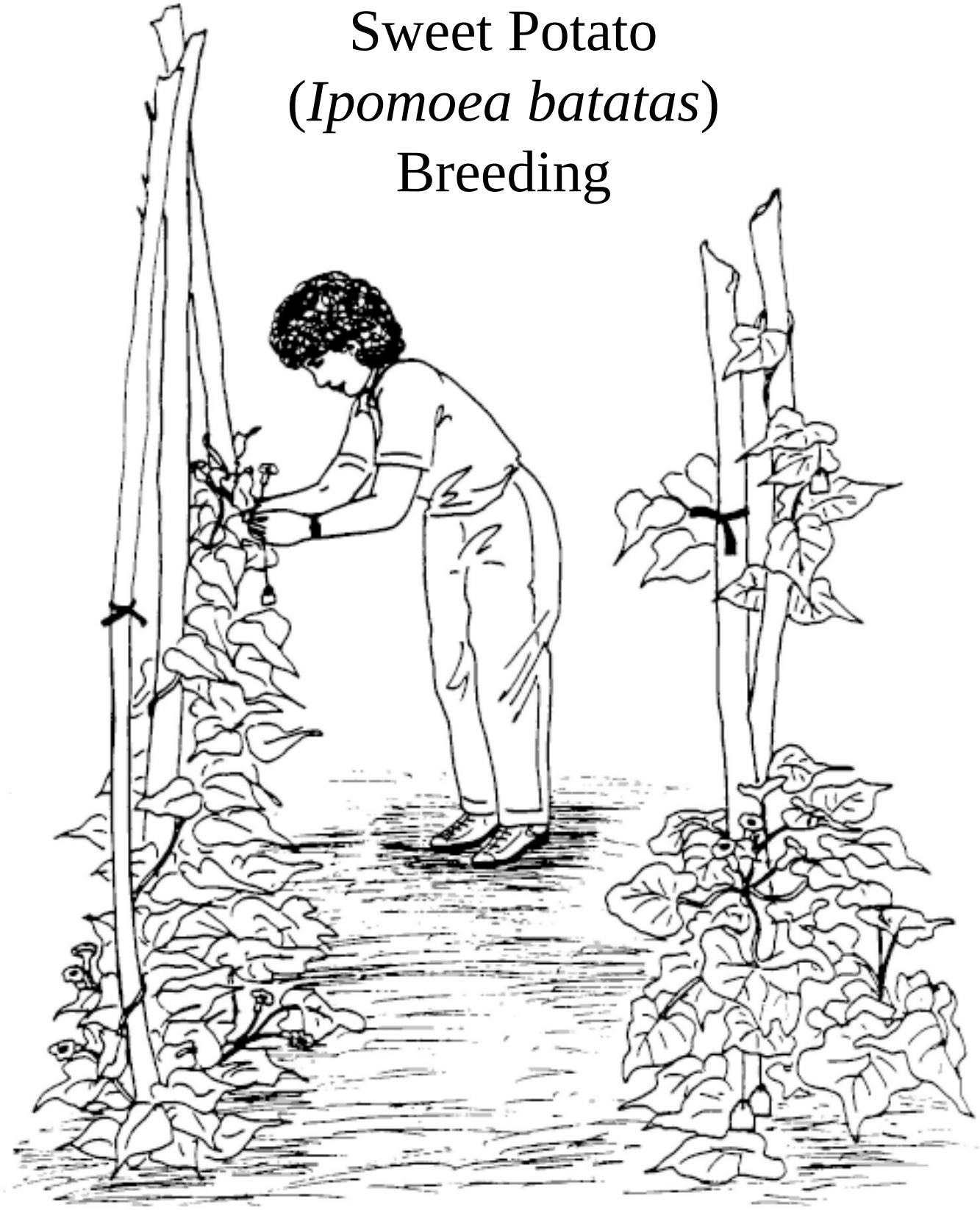
Sweet Potato (*Ipomoea batatas*) Breeding



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SWEET POTATO BREEDING

This manual is for researchers in the Pacific region who are starting sweet potato breeding programmes but lack training and experience in genetics and plant breeding. It is also for researchers and extension workers who are evaluating local and newly introduced sweet potato germplasm. It may also be useful to teachers and students of crop improvement courses at the diploma, degree, and postgraduate levels.

The objective of this manual is to provide you with the methods and techniques needed to carry out a sweet potato breeding programme. Practical aspects of breeding are emphasised, rather than theory. Use of technical terminology is minimized. To keep the manual concise, detailed explanations are avoided when possible, and many concepts are simplified. After learning the material presented here, you may want to read other texts to gain a more complete understanding of plant breeding.

Not all sweet potato breeders use the same breeding systems and techniques. The ones included here are appropriate to the developing-country conditions that most of us face, including limited laboratory and field facilities and limited funds for labour, equipment, and supplies.

These methods and techniques have proved successful in our breeding programme in the Kingdom of Tonga. This programme is a collaborative effort between the Tongan Ministry of Agriculture, Fisheries and Forests, the University of the South Pacific's Institute for Research, Extension and Training in Agriculture, and the Tongan/German Plant Protection Project.

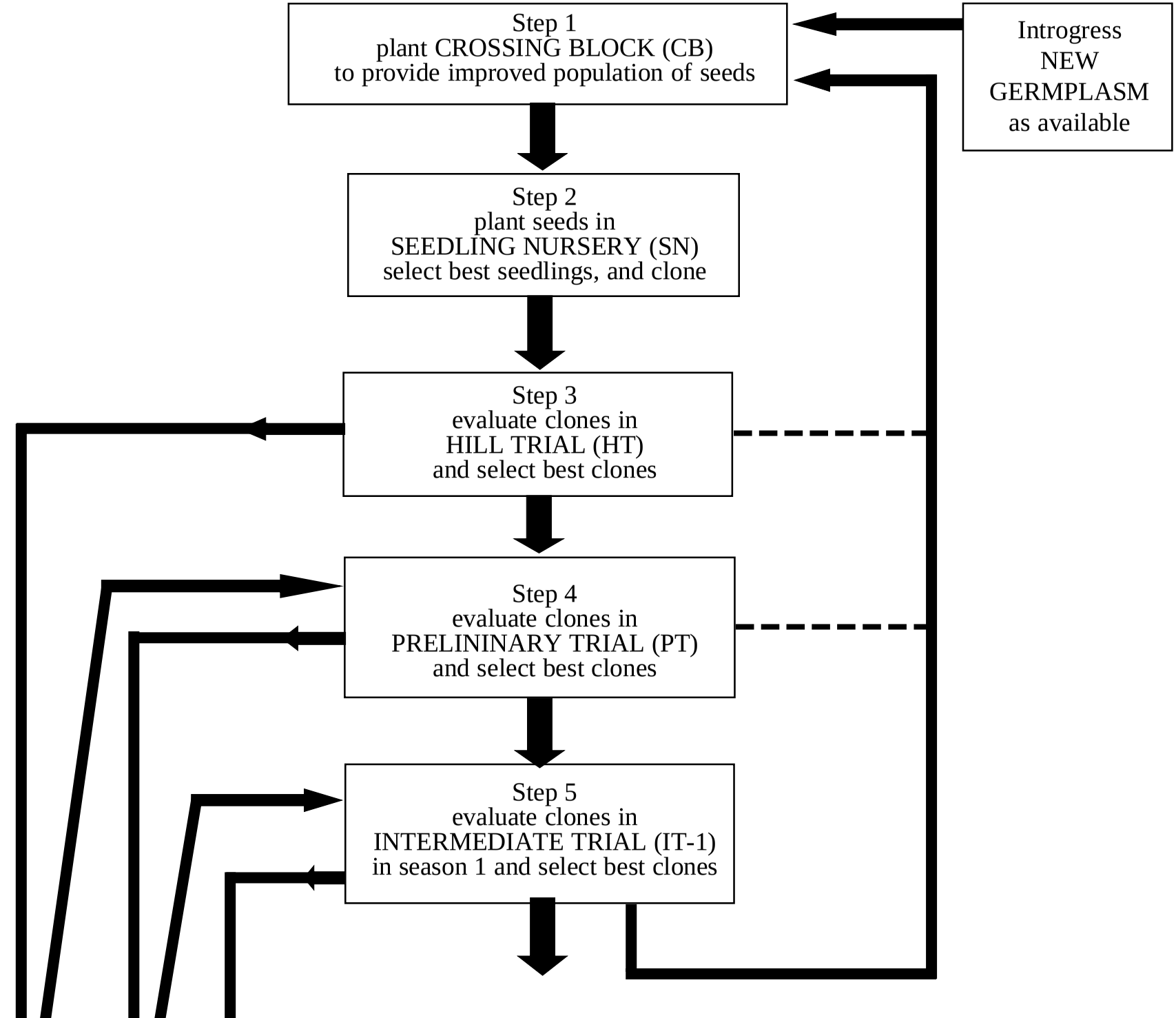
The methods and techniques presented here are important to the success of your breeding programme. Equally important is your knowledge of sweet potato production in your country, particularly your knowledge of yield-reducing factors such as environmental stresses and disease, insect, and nematode pests. You must also be familiar with the other problems farmers face and with the sweet potato quality characters favoured by farmers and consumers. Thorough knowledge of these factors is necessary to determine the goals of your breeding programme.

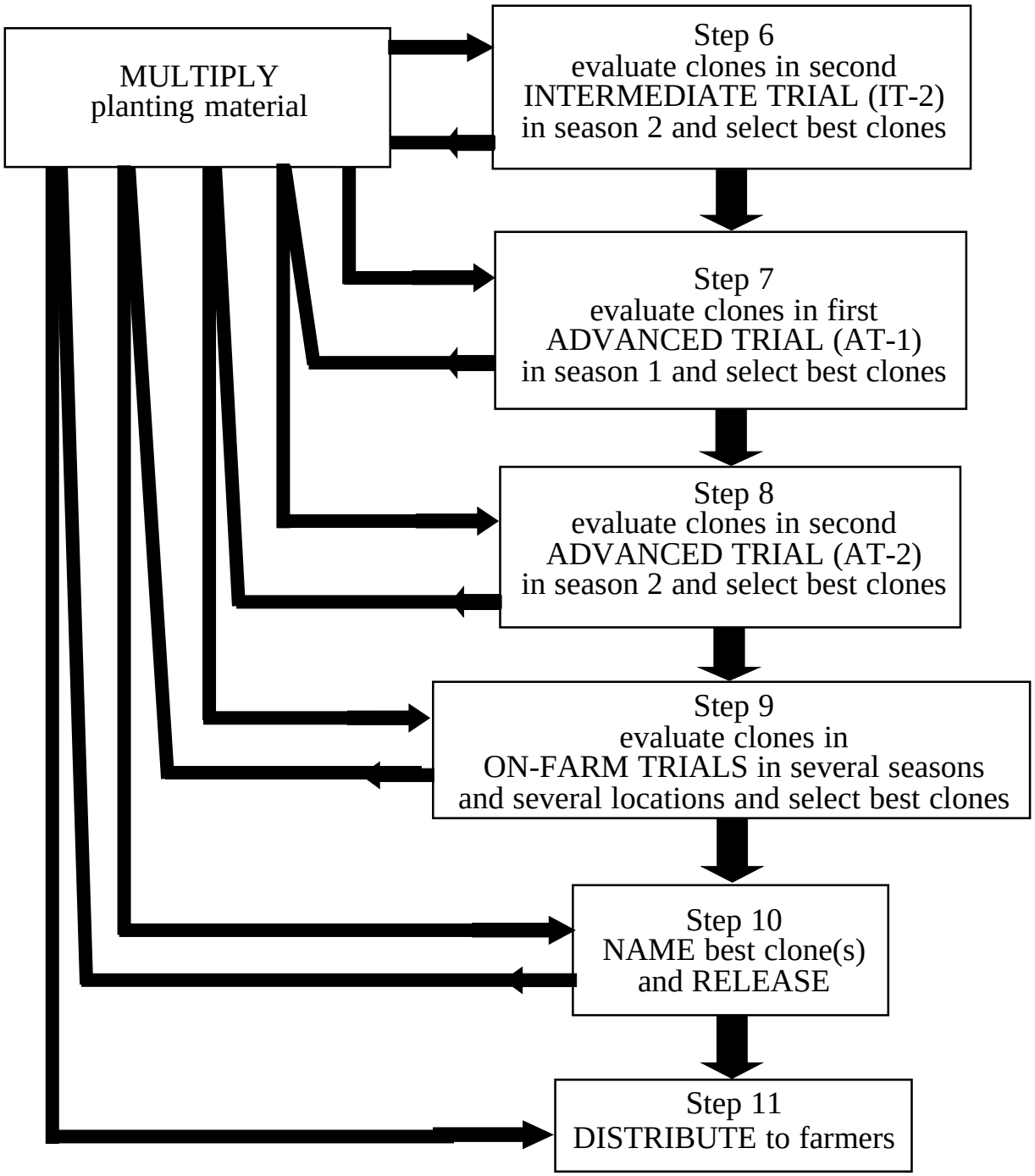
There are 3 methods to obtain improved cultivars (agricultural varieties) of sweet potato (*Ipomoea batatas*) for distribution to farmers in your country:

- Collecting, evaluating, and selecting from the local germplasm.
- Importing cultivars that have been bred in other parts of the world and evaluating them under your conditions.
- Breeding cultivars in your own programme.

This leaflet will concentrate on the last of these methods, that of breeding. However, much of the discussion under Steps 3 through 11, concerning conducting breeding trials and reducing experimental error, will be useful if you are evaluating local germplasm or imported cultivars.

Figure 1. Steps in a sweet potato breeding programme




MULTIPLY
planting material
Step 6
evaluate clones in second
INTERMEDIATE TRIAL (IT-2)
in season 2 and select best clones
Step 7
evaluate clones in first
ADVANCED TRIAL (AT-1)
in season 1 and select best clones
Step 8
evaluate clones in second
ADVANCED TRIAL (AT-2)
in season 2 and select best clones
Step 9
evaluate clones in
ON-FARM TRIALS in several seasons
and several locations and select best clones
Step 10
NAME best clone(s)
and RELEASE
Step 11
DISTRIBUTE to farmers

STEPS IN A SWEET POTATO BREEDING PROGRAMME

A proposed breeding procedure is outlined in Figure 1. In Steps 1 and 2, sexual propagation is used to produce seeds and seedlings. In Step 2, each seedling is cloned by propagating it vegetatively, and in all the following steps, vegetative propagation is used.

The purpose of using sexual propagation in Steps 1 and 2 is to create genetic variability. Each seedling produced during sexual propagation is genetically different from all others and is potentially a new, improved cultivar.

During Steps 3 through 5, you evaluate clones derived from the seedlings produced in Steps 1 and 2 to determine which ones you will advance to additional trials for further testing in Steps 6 through 9, which ones you will use as parents in the next Crossing Block (Step 1), and which ones you will discard.

During the On-Farm Trials (Step 9), you will identify one or more clones that both you and the farmers like. You are now ready to officially name and release these clones in Step 10 and distribute them to farmers in Step 11.

Figure 1 shows clearly that multiplication is a continuous activity that begins after you harvest the Hill Trial (Step 3), but the largest multiplication takes place between Steps 10 and 11 to produce enough planting material for distribution to farmers.

A clone consits of all the descendants of a vegetatively propagated individual.

Why do you go through the process of completing Steps 1 to 5 and then return some clones to Step 1? This is done to increase your chances of finding seedlings having all the characters you need in an improved cultivar. This process is called “population improvement”. During each breeding cycle, parent clones are selected and cross-pollinated in such a way that the resulting seedling population is improved. That is, it contains more good seedlings than previous seedling populations. The method of population improvement that many sweet potato breeders use, and that we use in Tonga, is called RECURRENT SELECTION. Recurrent selection, especially the step of choosing the parent clones that you plant in Step 1, determines the direction and success of your breeding programme; it is so important that a separate section is devoted to it later in this manual.

After a clone has been named and released, we generally call it a cultivar.

Although Figure 1 may look complex, it does in fact oversimplify a recurrent selection breeding programme, because it presents only one cycle. Recurrent selection is a long-term, continuous process with a new cycle of breeding (a new **Crossing Block**) started every year and with the chance for new and better clones ready for release every year.

Figure 2 tries to capture the more complex picture. It is important that a breeding programme be continued for long enough to benefit from the investments made in the early years. Do not expect to find the "perfect" clone in the first few years of the recurrent selection programme.

Your programme can include all 11 steps outlined above, or it can begin at Step 2 or 3 if you are collaborating with other breeding programmes. For example, if you receive seeds from another breeding programme, then you would start at Step 2. If you receive tissue cultures of improved clones from another breeding programme or you are evaluating your local germplasm, then you would start at Step 3.

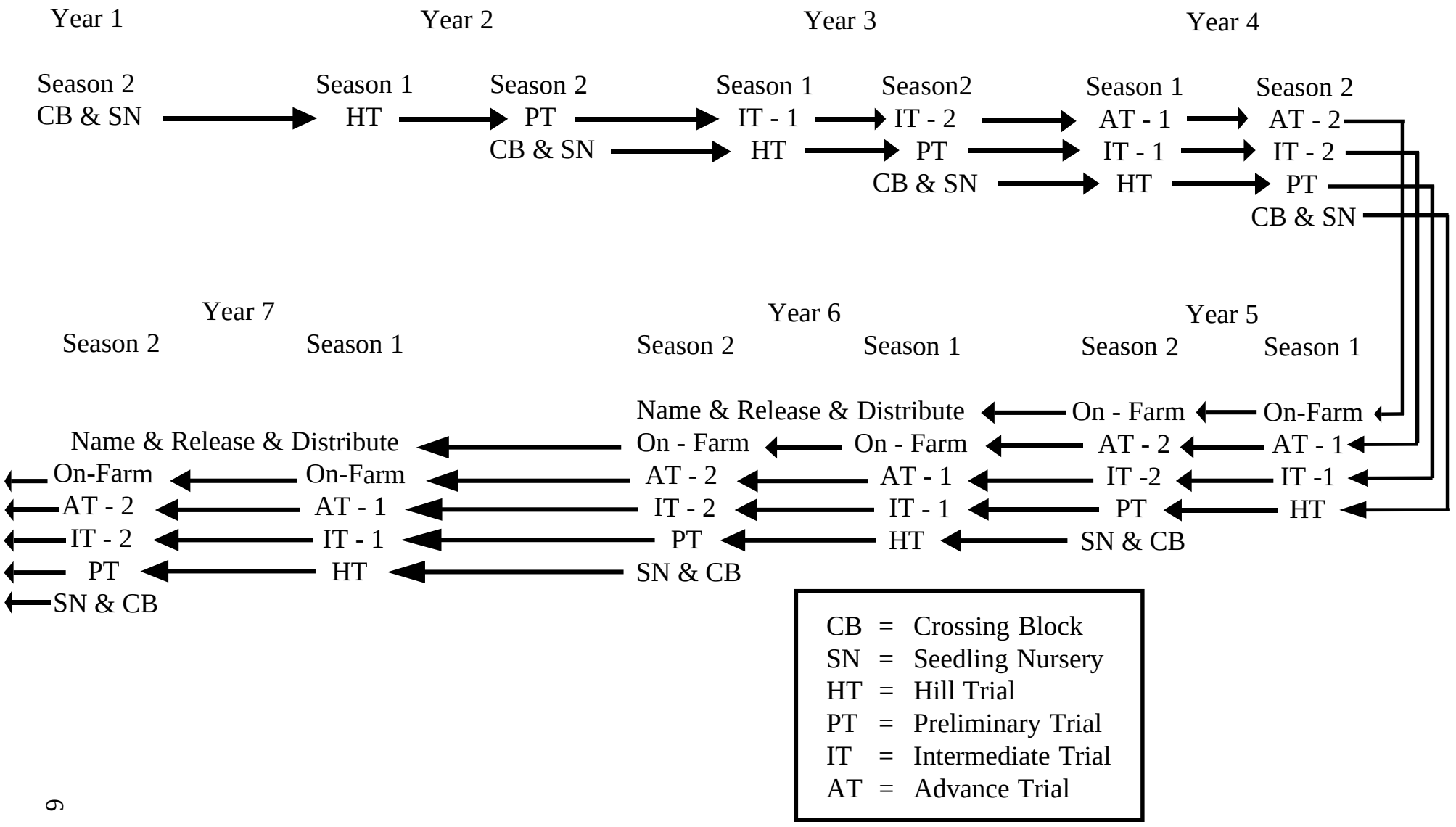
Step 1 – Plant Crossing Block to Provide Improved Population of Seeds

You can plant parent clones in a Crossing Block isolated from other flowering sweet potatoes and allow them to be open-pollinated by naturally occurring insects. This is called a "**polycross nursery**". Or, you can make controlled hand-pollinations to ensure that specific cross-combinations are represented in the seeds you produce. We use a combination of open-pollination and hand-pollination.

With open-pollination, you know the female parents of seeds but not the male parents. With controlled hand-pollination, you know both the female and male parents of the seeds.

Pollinating in a Crossing Block

Figure 2. Breeding is a long-term, continuous process with a new Crossing Block started every year. In this flow chart, 2 crops of sweet potato are grown each year (Seasons 1 and 2). The breeding program could be speeded up if 3 crops of sweet potato can be grown each year in your location.



The Crossing Block

Sweet potato flowers best during short days. Winter is therefore the best time for producing seed in the Southern Hemisphere.

In Tonga, we plant the crossing block during the first 2 weeks of April. Flowering begins about 1.5 months later and continues for 3 months. This means that we pollinate from May through August and harvest seeds from June through September.

In the Crossing Block, plant vine cuttings of the parent clones around the plants. We use 1 x 1 m, with 2 cuttings of the same clone at each planting position. Usually, 10 plants (5 planting positions) of each clone are enough, although you may need more plants of sparse-flowering clones and clones you plan to use in a large number of crosses.

At each planting position, erect a 2-m-tall stake. Train the main vines up the stake and tie them to the stake with inexpensive material. We use "bush twine".

Treated stakes last longer and can be reused another year.

Staking facilitates hand-pollination and insect-pollination, but staked plants are easily damaged by wind. If your Crossing Block is in a windy location, you should plant or construct a windbreak. We erect a "wall" of net shadecloth to block the prevailing wind.

Using a scissors, prune off all lateral branches and the tops of long vines that have reached the top of the stake. Be careful! Young flower clusters, which are also in the axils of the leaves, are easy to confuse with lateral branches. Do not prune off these flower clusters!

Do not fertilise the Crossing Block heavily with nitrogen, because lush, leafy vines produce few flowers.

Insects and diseases can reduce flowering and seed set. The Crossing Block should therefore be sprayed regularly, especially against sweet potato, weevils, leaf scab, and caterpillars that feed inside the flowers. To avoid killing bees and other pollinating insects, apply pesticides in the evenings, and use contact insecticides or baits rather than those with residual activity.

Birds sometimes eat sweet potato flowers. You can discourage them with birdchasers, such as metal tin lids or plastic bags attached by short lengths of string to a lattice of string between the stakes.

Pollinating is easier if you label each stake with the clone number.

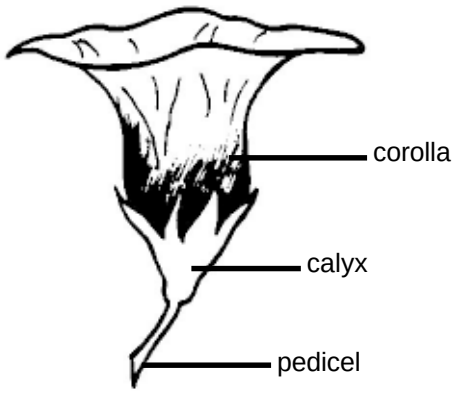
Floral Biology

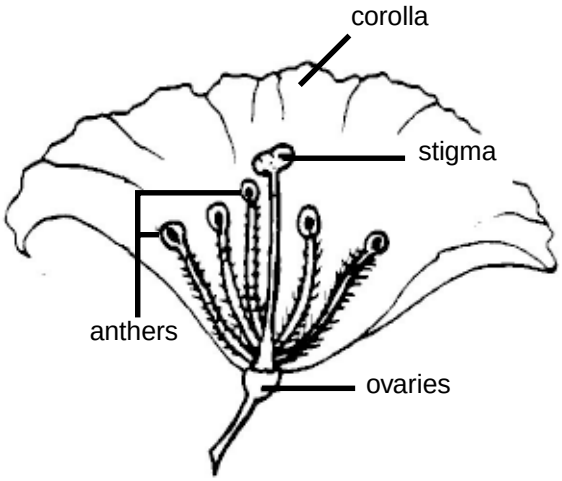
Most sweet potato clones flower naturally in the Pacific Islands and other tropical countries. It is not usually necessary to use grafting, girdling, or day-length control, which breeders in temperate regions use to induce flowering during long days.

Flowers occur in inflorescences, clusters of up to 22 buds growing out of the leaf axils. Each flower opens once, soon after daybreak, and usually fades by noon. It contains one stigma on top of the pistil (the female part) and 5 anthers on top of the 5 stamens (the male parts). The height of the stamens varies in different clones. If the stamens are shorter than the pistil, it is easy to find and pollinate the stigma, but if the stamens are the same height as or taller than the pistil, it is difficult to find and pollinate the stigma.

The enlarged base of the pistil contains 2 ovaries, and each ovary has the potential of producing 2 seeds. Therefore each fruit, which is called a capsule, can contain a maximum of 4 seeds. Hand-pollinated capsules usually contain only 1 or 2 seeds, and most openpollinated capsules contain 2 to 3 seeds.

Self-fertilisation in sweet potato is rare, because all clones have a high degree of self-incompatibility. Similarly, it may be difficult to obtain seed from crosses between certain parents, because cross-incompatibility also occurs.



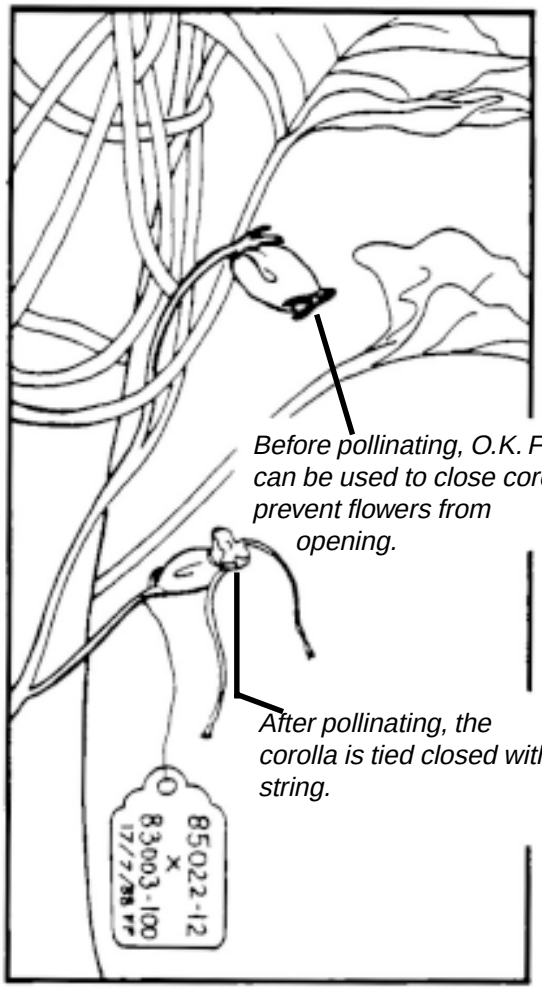


Controlled hand-pollination

To carry out a controlled hand-pollination in sweet potato, there are 4 steps:

1. preventing insect-pollination before hand-pollinating,
2. hand-pollinating,
3. preventing insect-pollination after hand-pollinating, and
4. labelling.

Since self-fertilisation rarely occurs in sweet potato, it is not necessary to emasculate (remove anthers from) the female parent unless you are carrying out genetic studies.

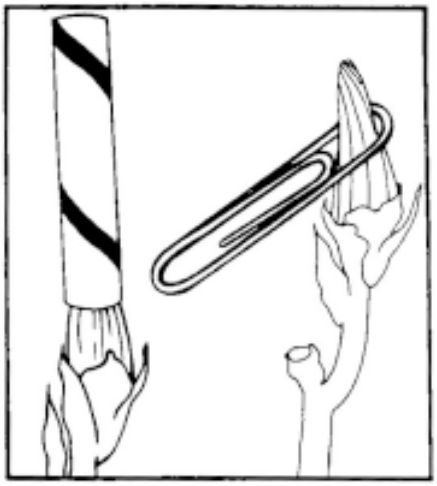


Before pollinating, O.K. Fasteners can be used to close corolla to prevent flowers from opening.

After pollinating, the corolla is tied closed with string.

Before pollinating, you must ensure that the flowers you plan to hand-pollinate are protected from pollination by insects. Protect the flowers on both female and male parent plants. To do this, select buds that will open the following morning and prevent each flower from opening by clipping the tip of the corolla with an O.K. Fastener (see Supplies), large paper clip, or small piece of drinking straw. Paper clips are the easiest to purchase, but we prefer O.K. Fasteners because they are lightweight. If you open these O.K. Fasteners carefully, you can reuse each one about 10 times before it breaks.

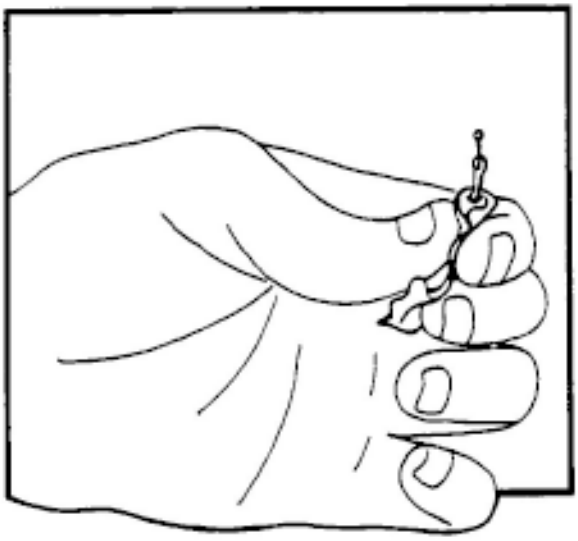
The best time to clip flowers for pollinating is late afternoon or evening on the day before you want to pollinate. At pollinating time it is easier to find the flowers you have clipped if you mark the plant with brightly-coloured, flagging ribbon, which you remove after pollinating.



Before pollinating, small pieces of drinking straw or paper clips can be used to prevent flowers from opening. Note the size of these buds; they will open the following morning.

The following morning, pollinate between sunrise and noon. Take a clipped flower from the male parent plant and carry it to the female parent plant. Gently remove the clip from the female flower without tearing the corolla, and spread the petals open. Remove the clip from the male parent, peel back the corolla to make a handle, and rub the anthers gently over the stigma of the female parent.

To prevent contamination of the female parent after pollination, carefully tie the corolla closed so that insects cannot reach the stigma. We use lightweight knitting wool or string.



Flower from male parent prepared for pollinating

Pollinating

NOTE: If you are producing seeds for a genetic study, you should emasculate the female parent to eliminate all possibility of self-pollination. To do this, select buds that will open the following morning. Use a one-sided razor blade to cut the corolla into 2 equal parts, from the tip down to the base. Do not damage the ovaries. Gently pull down each half of the corolla to remove the attached stamens. Cover the exposed pistil with a short length of drinking straw that has been closed at the top, pollinate as usual, and cover the pistil again with the drinking straw. If the drinking straw is paper, close it by bending over the top; if it is plastic, close it with an O.K. Fastener or staple. Remove the drinking straw 2 or 3 days after pollinating to permit the ovaries to expand.

To reduce contamination by undesired pollen, wash your hands or clean them with a damp cloth each time you change to a different male parent.

Label each pollination with the date and the names or numbers of the parents. Tie the label onto the pedicel of the individual flower that you pollinated, not below the inflorescence, which may contain open-pollinated flowers. We use small, white merchandise tags for labelling.

When you are first learning to pollinate, it is useful to also write on the pollinating label your initials, the time of day, remarks about the weather (very hot, rainy, etc.), and other comments that will help to improve your pollinating success rate.

By convention, breeders write the female parent first when labelling a cross. Therefore, in the sketch on p. 9, 85022-12 is the female parent and 83003-100 the male parent.

Your success rate for hand-crossing is affected by the weather, the health of the plant, the parents used, and your skill in pollinating. In the Tongan programme, about 48% of the flowers we pollinate develop into capsules, with an average of 2 seeds in each capsule.

Unless you want a particular maternally-inherited character, you can try using each clone as both a male parent and a female parent.

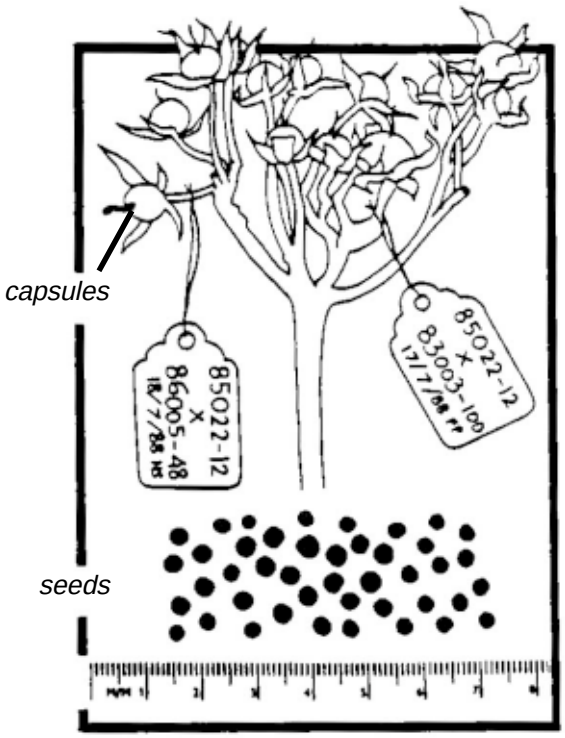
Throughout this manual, we have used the term sweet potato TUBER, rather than the technically correct term STORAGE ROOT or FLESHY ROOT. We have done this because tuber is commonly used and understood by agriculture workers and students in the Pacific Islands.

Harvesting Seeds

Seeds mature 4 to 6 weeks after pollination. Harvest each seed capsule when it is fully brown and the pedicel is dried and shrivelled. Check the Crossing Block regularly, capsules that are left too will dehisce (split open), scattering the seeds on the ground. Pick each hand-pollinated capsule, making sure that its label is attached. Label open-pollinated capsules with the name or number of the female parent.

In the lab, thresh out the seeds and discard any that are lightweight or show signs of insects or fungus. Put sound seeds into labelled envelopes, record the number of seeds on the envelope, and store. You can put seeds from different hand-pollinated capsules into one envelope if they have the same female and male parents, or, in the case of open-pollinated seeds, if they have the same female parent.

To simplify record-keeping, we often bulk together different crosses, for instance, all open-pollinated seeds harvested from clones that performed well in the Advanced Trial. When bulking together more than one cross, you can make sure that all parents are equally represented by bulking equal numbers of seed from each female parent or each cross combination.

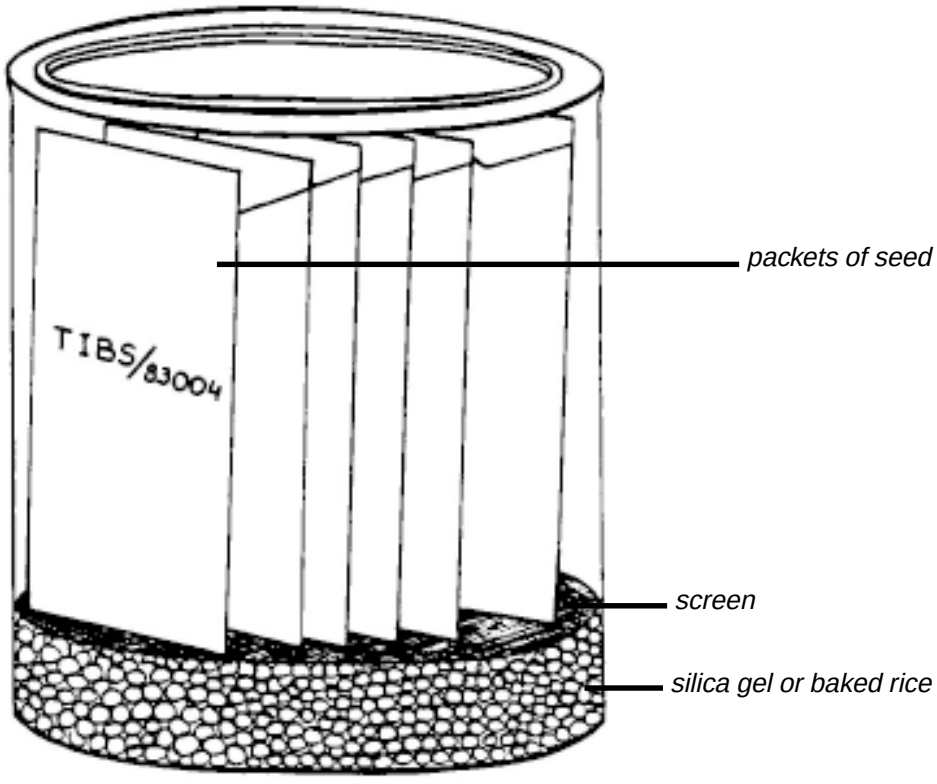


NOTE: Seeds with low viability are usually lightweight and can be separated from sound seeds by floating. Put seeds into a container of water to which a few drops of a surfactant or detergent has been added. Discard the light seeds that float. Save the heavy, sound seeds that sink to the bottom, but be sure to thoroughly dry them before storing.

Seed Storage

Sweet potato seeds will remain viable for up to 20 years in wellcontrolled storage conditions (18°C, 50% RH), and for at least 5 years when stored in a desiccator in the refrigerator. We make an inexpensive desiccator from a tin or glass jar with a tight-fitting lid. In the bottom of the tin or jar we place a layer of the desiccant, silica gel. The indicating type is best, since you can see by the change in colour from blue to pink that it needs to be dried.

If you do not have silica gel, you can use uncooked rice that has been baked in a low-temperature oven until very dry and light brown. Try to find at least a small quantity of indicating silica gel to mix with the baked rice so you can see when the rice needs to be dried again. Place a piece of screen over the desiccant before adding the envelopes of seeds.



You can make an inexpensive desiccator for storing seeds.

Record Keeping

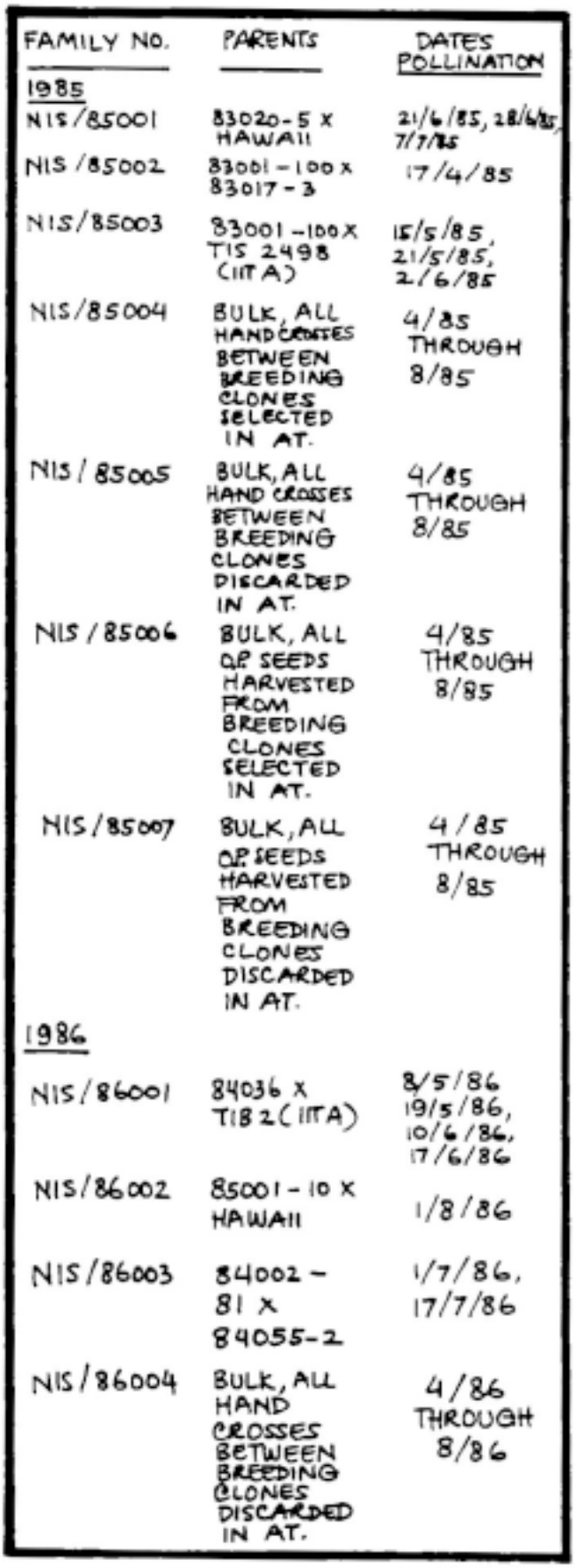
Record keeping is an important part of a breeding programme. With some methods of breeding, like pedigree breeding, it is essential that you be able to trace the pedigree of a clone back through many generations. With recurrent selection, however, knowing the pedigree of each clone is not always important, and that is why we often bulk seeds together. There are some instances when knowing the pedigree of a clone will help improve your breeding programme, and that is why we keep seeds of some crosses separate.

Different breeders prefer different methods of recording pedigrees. Here is the one that we use:

When seeds are harvested from the Crossing Block, each bulked seedlot or individual cross is assigned a family number, for example, NIS/86001. NIS indicates seed (S) of sweet potato (I=*Ipomoea*) produced in Nualei (N), Tonga, and 86001 is the family number (86 = 1986, the year the seed was harvested).

When the seedling nursery is harvested, we assign a clone number to each seedling that is selected to go into the Hill Trial. This clone number consists of the family number followed by -1, -2, -3, etc., for example, 86001-1. This clone number is a PERMANENT number, and does NOT change from year to year.

Keep handwritten records in a bound record book–do NOT risk typing errors.



FAMILY NO.	PARENTS	DATES POLLINATION
1985		
NIS/85001	83020-5 x HAWAII	21/6/85, 28/6/85, 7/7/85
NIS/85002	83001-100 x 83017-3	17/4/85
NIS/85003	83001-100 x TIS 2498 (IITA)	15/5/85, 21/5/85, 2/6/85
NIS/85004	BULK, ALL HAND CROSSES BETWEEN BREEDING CLONES SELECTED IN AT.	4/85 THROUGH 8/85
NIS/85005	BULK, ALL HAND CROSSES BETWEEN BREEDING CLONES DISCARDED IN AT.	4/85 THROUGH 8/85
NIS/85006	BULK, ALL OP SEEDS HARVESTED FROM BREEDING CLONES SELECTED IN AT.	4/85 THROUGH 8/85
NIS/85007	BULK, ALL OP SEEDS HARVESTED FROM BREEDING CLONES DISCARDED IN AT.	4/85 THROUGH 8/85
1986		
NIS/86001	84036 x TIB2 (IITA)	8/5/86 19/5/86, 10/6/86, 17/6/86
NIS/86002	85001-10 x HAWAII	1/8/86
NIS/86003	84002-81 x 84055-2	1/7/86, 17/7/86
NIS/86004	BULK, ALL HAND CROSSES BETWEEN BREEDING CLONES DISCARDED IN AT.	4/86 THROUGH 8/86

Step - 2 Plant Seeds in Seedling Nursery

Scarifying Seeds

Since sweet potato seeds have very hard seedcoats, they germinate slowly and irregularly unless they are scarified. The easiest way to scarify large quantities of seeds is to soak them in concentrated sulfuric acid.

If you have only a few seeds, you can hand-scarify them by scratching a small notch in each seedcoat with a sharp needle or a small, 3-cornered file. Do not scratch the round side of the seed, since this will damage the embryo.

For very important lots of seeds, you can acid-scarify first, and then hand-scarify any seeds that have not germinated or swollen 2 days after moistening them in petri dishes.

We use the following method for scarifying seed: Caution: THE FUMES OF SULFURIC ACID ARE DANGEROUS, SO WORK IN A FUME CABINET OR OUTSIDE AWAY FROM BUILDINGS AND PEOPLE. We pour concentrated sulfuric acid (98% H_2SO_4) into a GLASS beaker large enough for the quantity of seeds we want to treat. We wrap the seeds in acid-proof fly screen (test a small piece in the acid before wrapping the seed) and label with a metal label. Then, using the metal wire on the label as a handle, we soak the seeds in the sulfuric acid for 40 minutes. Still working in the hood or outside, we pull the bundle of seeds out of the sufuric acid and rinse in 2 beakers of water, one after the other. Then it is safe to take the bundle to a tap and rinse the seeds under running water for 5 to 10 minutes. Using this method, we normally get 95% germination.

Seed Germination and Seedling Rearing

Immediately after scarifying and rinsing the seeds, place them in petri dishes lined with wet filter paper, paper towel, or tissues. Do not add too much water; there should be no free water in the bottoms of the petri dishes. Up to 150 seeds will fit into one petri dish. Cover the petri dishes and keep them in the lab at ambient temperature and light. Germination usually starts 1 to 2 days after wetting. Transplant germinated seeds to the nursery bed as soon as you can see the radicles, because transplanting is very difficult if you delay until the radicles are longer.

We also plant seeds that are swollen but have not yet produced radicles; they will usually germinate in the nursery bed.

Plant germinated seeds at a spacing of 30 cm between rows and 15 cm between plants.

For our nursery beds, we mix together topsoil, sand, and rotten (composted) chicken manure and fumigate with Basimid. (Check to see if this is legal in your area.) If vine growth during the season is not vigourous enough, we fertilise with NPK. And we use slug bait to protect the young seedlings.

Seedlings are ready to harvest when most of them are large enough to provide 3 vine tip cuttings. In Tonga, this is about 2.5 months after sowing.

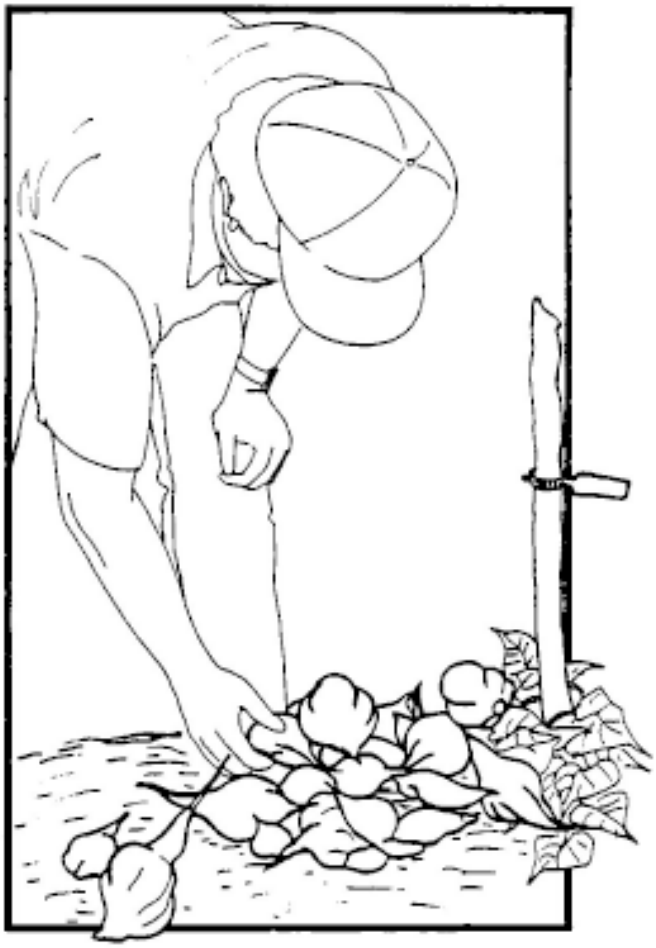
Steps 3 Through 9 - Evaluating and Selecting Clones

In these steps, you evaluate the breeding clones in a series of 6 trials located on the research station, followed by trials in farmers' fields. Note that the Intermediate and Advanced Trials and the On-Farm Trials are each planted in 2 seasons, wet and dry. Our goal is to find breeding clones that perform excellently in the dry season and at least satisfactorily in the wet season.

At the end of each trial, you must make decisions whether to select a clone for further trial, or to discard it, or to use it as a parent in the Crossing Block. Usually, you select 10 to 50% of the clones for further trial.

In Hill and Preliminary Trials you have large numbers of clones, but each clone is represented by only a few plants. In Intermediate and Advanced Trials you have fewer clones, but more plants in each clone. For instance, in a Hill Trial you might have 1000 clones with 3 plants/clone, compared to the Advanced Trial with 5 clones and 24 plants/clone/replication, 4 replications. With the small number of plants/clone in Hill and Preliminary Trials, it is not possible to judge very accurately such characters as yield. That is why we use subjective ratings during these trials and do not begin to actually count and weigh yield until the Intermediate Trials.

Which characters should you evaluate when selecting clones? This will depend on the goals of your breeding programme, but to give you some ideas, we have included in Table 1 the characters that we evaluate in each trial in the Tongan breeding programme.



Evaluating large numbers of breeding clones in field trials requires careful observation of many plant and tuber characteristics. It requires patience, persistence, scientific skills and a "good eye". Plant breeding is both an art and a science.

Conducting Trials

Here are some pointers for conducting these trials:

1. **Trial Conditions**. Ideally, trials should be carried out in as many sites as possible, but practically we are often limited to one or two sites. Therefore, choose your trial sites carefully to include as many as possible of the relevant biological and physical constraints faced by the farmers. In other words, you should carry out your trials under conditions similar to those faced by farmers (or home gardeners).

Do not make the common mistake of conducting your trials under optimum conditions by adding fertiliser and water, controlling all pests and diseases, etc. If you do, you may end up selecting breeding clones that perform well under optimum conditions but perform poorly under the farmers' less than optimum conditions. For instance, if farmers grow most of their sweet potatoes on low fertility soil, then you should grow your trials without adding fertiliser. If farmers do not irrigate, you should not irrigate your trials, and so on.

Obviously, there are times when you must break this rule in order to accomplish your breeding goals. For instance, if you are selecting for leaf scab resistance, you might need to apply small quantities of overhead irrigation to wet the leaves and maintain high relative humidity, in order to encourage disease spread. Also in your trials, especially the Hill Trial, you may need to use a spacing wider than the farmer's in order to make evaluation possible.

2. **Disease and Pest Control**. In your trials, you should normally NOT control the diseases, insects, or nematodes to which you are selecting resistance, even if farmers do use control measures. For instance, many farmers in Tonga control leaf scab with fungicides, but we do not apply fungicides to our breeding trials.

However, it may be necessary to use some control measures to reduce damage by diseases, insects, or nematodes if the level of resistance in your breeding populations is still relatively low. For instance, the level of weevil resistance in our breeding clones is low. If we apply no control measures, the weevils destroy most tubers, and it is not possible for us to select for other characters such as yield and eating quality. We do, however, want to be able to identify and discard clones that are highly susceptible to weevils. Therefore, we apply control measures (hilling-up during the growing season, weevil traps) that reduce weevil damage but do not eliminate it. Another example is little leaf disease. The level of resistance to this disease in our breeding clones is low, and if it is spreading rapidly through our trials, we control it by rogueing out diseased plants.

If you are NOT evaluating your breeding clones for certain pests, you should control them in your trials if the damage they cause will obscure the characters you are evaluating. For instance, we control rats (with bait), leaf miners, and horn worms when populations are high.

Table 1. Character evaluated in each trial in the Tongan breeding programme.

Trial	Planting Pattern	Characters
Seedling Nursery (SN)	30 x 15 cm; 1 plant/clone.	leaf scab score (at harvest), vine length, vine thickness, twining (vine climbs or does not climb), tuber skin colour, tuber flesh colour.
Hill Trial (HT)	100-200 x 90 cm between planting points; 3 plant/ planting point; 1 planting point.	leaf scab score (average over season), little leaf score, virus score, rose beetle score, vine length, vine thickness twining, tuber skin colour, tuber flesh colour, yield (high, medium, low), specific gravity of clones selected in field
Preliminary Trail (PT)	100 x 90 cm between planting points; 3 plants/planting point; 6 planting points (use inside 4 planting points for data).	leaf scab score (average over season), little leaf score, virus score, rose beetle score, vine length, vine thickness twining, tuber skin colour, tuber flesh colour, tuber shape, weevil damage, tube smoothness, tuber cracking, precocious tuber sprouting, tuber appropriate for market and/or ceremony, tuber yield (high, medium, low), tube number (high, medium, low), tuber size (large, medium, small), specific gravity.

Table 1 continued

Intermediate Trials (IT - 1 and IT - 2)	100 x 90 cm between planting point; 3 plants/planting point; 6 planting points/rep (use inside 4 planting points for data); 3 reps; 2 seasons.	leaf scab score (average over season), little leaf score, virus score, rose beetle score, vine length, vine thickness, twining, tuber skin clour, tuber flesh colour, tuber shape, weevil damage, tuber smoothness, tuber cracking, precocious tuber sprouting, tuber appropriate for market and/or ceremony, marketable weight tubers (weigh), marketable number tubers (count), edible weight tubers (weigh), edible number tubers (count), total weight tubers (weigh), total number tubers count, field selection, specific gravity.
Advanced Trials	100 x 90 cm between planting points; 3 plants/planting point; 6 planting points/row, 4 rows/ rep (use inside 8 planting points for data); 4 reps; 2 seasons.	same as IT plus tuber dry weight, eating quality.
On Farm Trials	spacing and planting pattern determined by farmer; number of plants and reps determined by availability of planting material and land; best located in the middle of farmer's own sweet potato production field.	leaf scab score (average over season), little leaf score, virus score, rose beetle score, marketable weight tubers (weigh), marketable number tubers (count), edible weight tubers (weigh), edible number tubers (count), total weight tubers (weigh), total number tubers (count) with farmer deciding which tubers are marketable and edible, eating quality as judged by farmer and family, farmer's overall opinion of breeding clones and farmer's choice of which ones he/she will grow again.

3. **Local Checks**. You must always include in your trials one or more local check cultivars. A local check is a cultivar that is presently popular and grown by many farmers in your location, or a cultivar that is presently recommended by the Extension Division. Why is it necessary to include a local check? Because the purpose of your trials is to identify breeding clones that are as good as, or better than, the cultivars that farmers are already growing. Local checks are treated like breeding clones in that they are randomised and included in all replications.

4. **Susceptible and Resistant Checks**. If you are evaluating your breeding clones for disease, insect, or nematode resistance, you should also include in your trials a susceptible check cultivar and a resistant check cultivar for each of these constraints.

A susceptible check is one that you know is susceptible to the disease (or insect or nematode). It helps you to determine whether the disease (or insect or nematode) is present in your trial and at what level. For leaf scab, for instance, if your susceptible check is severely infected with the disease, then breeding clones in the same trial that show mild or no infection are most likely resistant to this disease, and you can select them for further trial. However, if your susceptible check does not become infected with leaf scab, then you cannot evaluate the breeding clones for resistance, because the disease is not present in the trial, or the environment is not favorable for its spread. If all rows of the susceptible check in the different replications show symptoms of the same intensity, then you know that the disease is uniformly spread in the trial.

A resistant check helps you to determine the LEVEL of resistance of each breeding clone. Is it the same, higher than, or lower than the resistant check cultivar?

In Intermediate, Advanced, and On Farm Trials, treat the susceptible and resistant checks the same as the breeding clones by randomising them in each replication. In Hill and Preliminary Trials containing large numbers of breeding clones, repeat the susceptible and resistant checks several times, about once for every 10 breeding clones.

5. **Spreader Rows**. When evaluating for resistance, it is important to have high levels of the disease, insect, or nematode present in your trials so that you can distinguish between resistant and susceptible breeding clones. Therefore, locate your trials at sites where the disease, insect, or nematode is naturally epidemic.

You can also increase the amount of disease inoculum available to infect the trial by planting “spreader rows”–rows of infected plants of a susceptible cultivar. But, be very careful to plant these rows so that all clones in the trial are an equal distance from the spreader rows. See Figures 4, 5, 6, and 7 for examples. Similarly, you can increase the number of insect pests in your trial with spreader rows of infested plants or plant parts. For example, spreading around tubers infected with weevils will increase the weevil population in your trial.

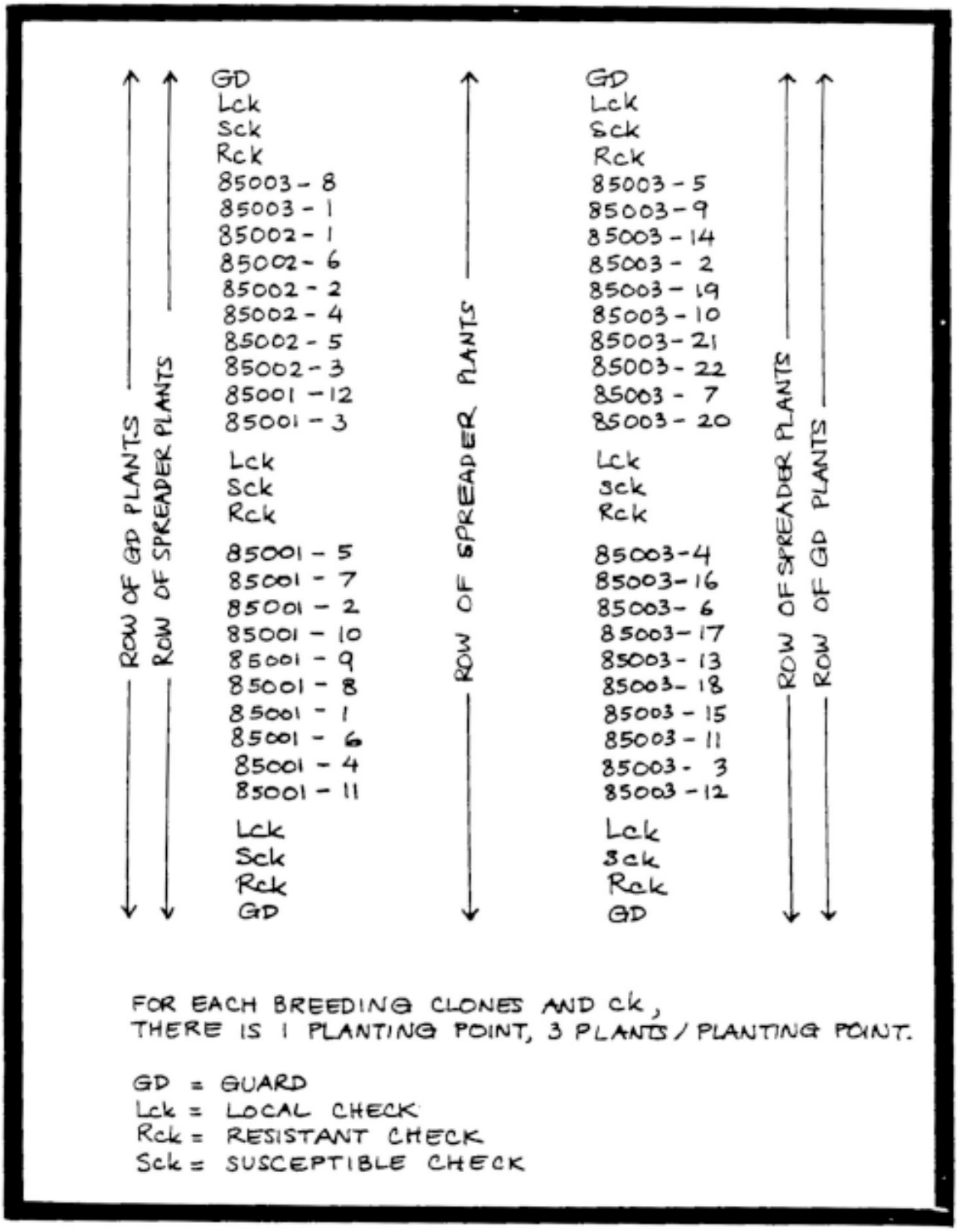


Figure 4. Example of the layout of *part* of a Hill Trial.
Note positions of guard rows and spreader rows.

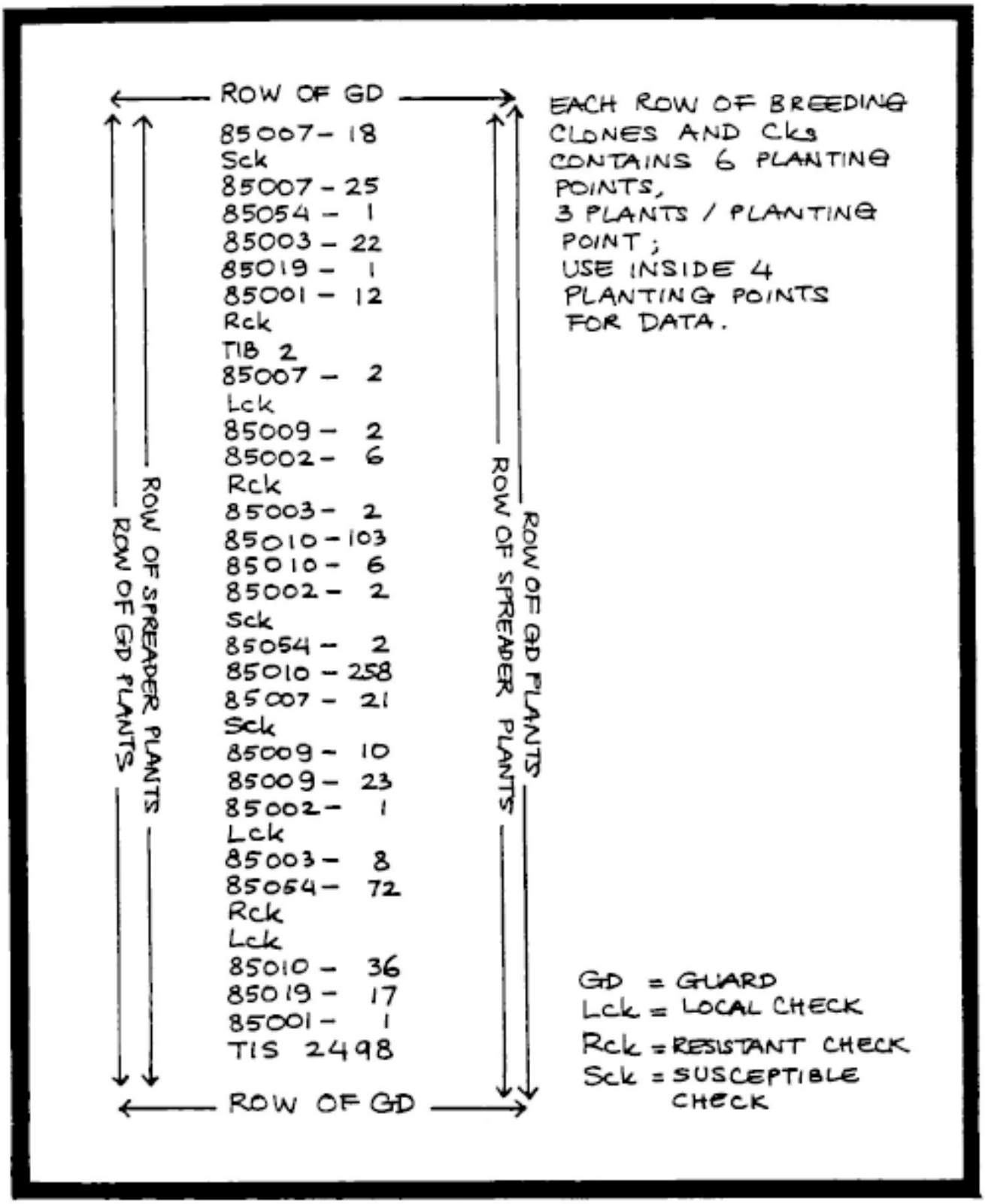


Figure 5. Example of the layout of a Preliminary Trial. Note positions of guard rows and spreader rows. Most of your Preliminary Trials will be larger than this one.

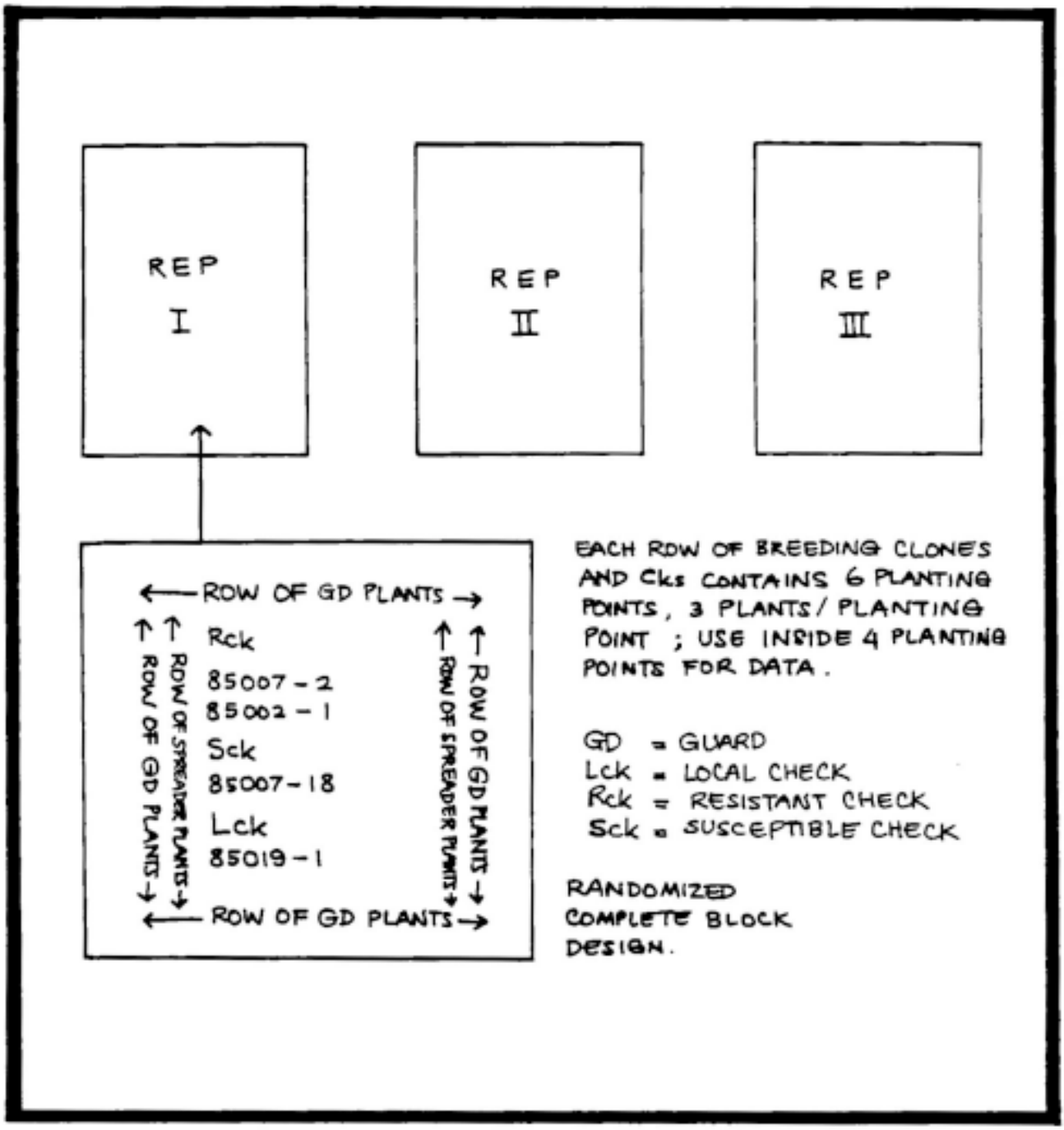


Figure 6. Example of the layout of an Intermediate Trial. Note positions of guard rows and spreader rows. Most of your Intermediate Trials will be larger than this one.

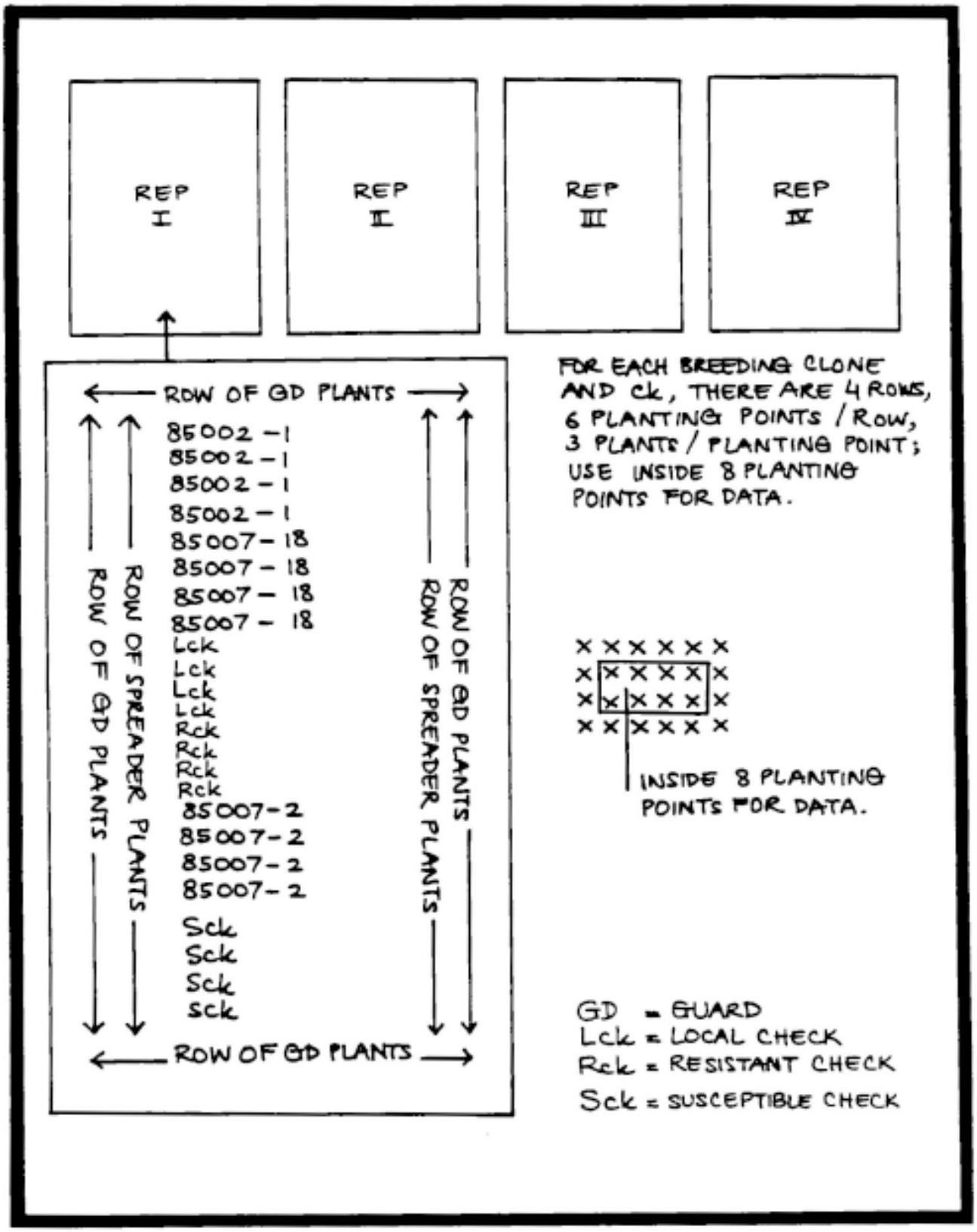


Figure 7. Example of the layout of and Advance Trial. Note positions of guard rows and spreader rows. Most of your Advanced Trials will be larger than this one.

6. **Guard Rows**. In all field trials, guard rows (often called border rows) are essential. All data plants (plants that you will observe, measure, and collect data from) must be surrounded by 4 other plants in order to eliminate the "wedge effect". Or, if you are planting more than one cutting at a planting point, then all data planting points must be surrounded by 4 other planting points in order to eliminate the "wedge effect". See Figures 4, 5, 6, and 7 for examples. If you do not take the precaution of planting guard rows, then data plants on the edge of the plot will have more space and will be more vigourous and higher-yielding than plants in a typical field situation.

Extra guard rows can also be planted to "guard" the trial from damage by tractors, trucks, and foot traffic. For guard rows, choose cultivars that have vine types similar to most clones in the trial.

In Preliminary and Intermediate Trials, the first and last planting points in each row act as guard rows, and it is easiest to use the same clone. This means that you plant 6 planting points in each row of a clone and harvest the inside 4 for data.

7. **Labelling and Mapping**. At planting time, one of the most important precautions you should take to avoid errors is to properly label all clones and to map nursery beds, trials, and multiplication blocks IMMEDIATELY after planting. Label stakes may be lost because a farm worker needs wood to start a cooking fire or a stake to scrape mud off his shoes! Make a permanent map of the trial layout and keep it in a safe place so that clones can be accurately located even if every label is moved or destroyed. For orientation, include compass directions and permanent landmarks like buildings or large trees.

In this permanent record, also write planting dates, harvest dates, dates of important operations like hilling-up, fertiliser and pesticide applications, dates when data were taken, and information on spacing, number of plants per planting place and row.

8. **Vine Types**. When you grow clones of different vine types in adjacent rows in your trials, clones with short, compact vines and small leaves are sometimes covered by neighbouring clones with long, vigorous vines and large leaves, especially during the rainy season when vines are very vigourous. Consequently, the compact types may yield poorly, not because they are genetically low-yielding, but because their leaves are buried under other vines. This is not a problem in Advanced Trials, in which 4-row plots are used, or in On-Farm Trials, in which larger plots of each clone are used, but it is a problem in Hill, Preliminary, and Intermediate Trials, in which single-row plots are used.

We reduce interrow competition in Hill Trials by planting breeding and check clones 2 m apart with a scab-susceptible spreader row planted in between. At mid-season, when the longer vines have started to invade neighbouring rows, we pull out these spreader rows, which have already completed their function of spreading leaf scab inoculum. We also give the "benefit of doubt" to small-vine clones that have been covered by their neighbours and select them for further trials even if their yields are low. In Preliminary and Intermediate Trials, we plant 2 separate trials, one for normal, long vine types and a second for compact types.

9. **Selection**. To save land and labour, it is essential that you discard undesirable clones as early in the trial sequence as you can accurately identify them. However, in the Hill and Preliminary Trials, where there are no replications and only a few plants of each clone, you must be careful when evaluating characters like yield that are strongly influenced by the environment. Keeping this caution in mind, you should try to identify clones that have poor yields and discard them, especially when your decision is reinforced by other negative characters such as disease susceptibility or late maturity.

In these unreplicated trials, concentrate more on highly heritable characters such as skin colour, flesh colour, and broad categories of vine type, such as compact and normal vining types.

Concentrate also on discarding the poorest cultivars rather than on selecting the best. For example, you may not be able to accurately identify clones that are resistant to leaf scab, but you can discard any that show severe symptoms of the disease. Clones with obviously poor yield, poor tuber shape, veining, cracking, or otherwise unacceptable tuber appearance can be discarded in these early trials.

From each trial, you usually select 10 to 50% of the clones for planting in the next trial. Therefore, you must start with a large number of seedlings.
For example:

2000	seedlings
1000	seedlings in HT
100	clones in PT
25	clones in IT - 1
13	clones in IT - 2
7	clones in AT - 1
5	clones in AT - 2
2	clones in On-Farm

10. **Experimental Error**. There are several ways you can reduce variability and thus experimental error in your trials. At planting, use all vine TIP cuttings of the same length, from plants that are the same age. Sort these cuttings into piles according to vigour and health and plant the “best” in replication 1, the “second best” in replication 2, the “third best” in replication 3, etc. If you do not have enough tip cuttings to plant the entire trial, you can use non-tip cuttings for non-data plants.

Throughout the growing season, apply all treatments uniformly to all clones in a replication. This includes treatments such as planting depth and style, fertiliser, pesticides, rat bait, irrigation, hilling-up, and weeding.

Carry out operations like weeding and hilling-up by replication, and if you cannot complete the entire trial at one time, break after completing a replication, not in the middle of a replication.

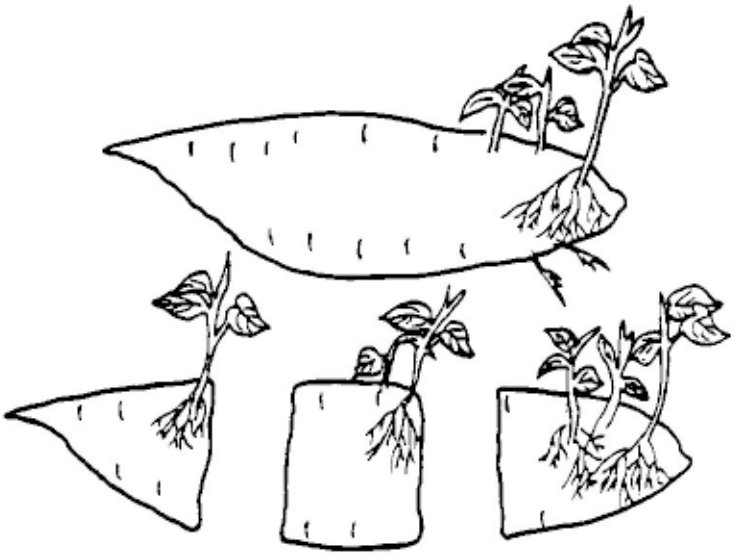
Each field worker treats sweet potato a little differently, in terms of planting, weeding, hilling-up, etc., and therefore, if more than one worker is applying a treatment, assign one worker to complete one replication. For example, when we plant our trials, all of replication 1 is planted by one worker, all of replication 2 by another worker, etc. You must also take the same precautions when collecting data. If it begins to rain for instance, finish the replication before you stop. If more than one worker is collecting data, each worker must complete a replication; NEVER have different workers evaluate different clones within the same replication.

Step 10 - Name and Release the Best Clones

After you have made your final selections in the On-Farm trials, you are ready to name and officially release the selected breeding clones as improved cultivars. To inform the public about this release, you can use radio, newspaper, extension leaflets, displays at agriculture shows, and demonstration plots planted by the Extension Division.

Step 11 - Distribute New Cultivars to Farmers

The breeder's job is NOT completed until the new cultivar has been distributed to farmers. This step requires large-scale multiplication of high quality planting material and collaboration with the Extension Division, farmer groups, shools, etc.



Both vine cuttings and tuber sprouts can be used to multiply clones.

Multiplication

During each season it is necessary to multiply enough planting material for the next season's trials. And after a cultivar has been released, large amounts of planting material need to be multiplied for distribution to farmers.

Cuttings taken from 2.5-month-old plants are best for planting trials. Therefore, it is not good to take cuttings to plant the next trial from a trial you are harvesting. In Tonga, we plant one multiplication plot at the same time as the trials. Then we take cuttings from this first multiplication plot to plant a second multiplication plot 2.5 months before the expected planting date of our next series of trials. In this way, the second multiplication can provide cuttings that are just the right age for planting the trials.

We keep multiplication plots sprayed against weevils, rose beetle, and leaf scab disease, especially if we are multiplying planting material for distribution to farmers.

Use both vine cuttings and tuber sprouts for multiplication. One vine cutting will produce about 5 vine cuttings, and 1 average-size tuber will produce about 20 vine cuttings.

When using vine cuttings for multiplications, you can increase the multiplication rate by using both tips and middle sections of the vines, but avoid using vine bases, because they are likely to carry weevils.

Producing vine cuttings from tubers is easy. Tuber dormancy varies, but tubers are usually ready to plant 2 to 3 weeks after harvest, when they are just beginning to sprout. Cut average size tubers into 2 pieces and large-size tubers into 3 pieces. Plant these pieces in furrows if rainfall is low to average or on mounds or ridges if rainfall is high. Cover tuber pieces with 5 to 8 cm of soil.

Most tuber pieces produce a large number of sprouts, but these are too crowded to grow properly. Therefore, when sprouts are young pull off the weak ones, leaving only 4 or 5 strong sprouts to grow. When these sprouts are about 30 cm long, pinch off their tips to encourage branching.

To keep each clone true-to-type, always carefully select the planting material used for multiplication. It is also necessary to walk your multiplication plots regularly and pull out all "off-type" plants. These off-type plants can occur in your clones for several reasons. "Volunteer" plants may grow from tuber and vine pieces remaining from previous crops of sweet potato grown on the same field. Naturally set seeds may fall to the soil, germinate, and the seedling vines may be mistakenly harvested together with the parent vines. Mutations occur frequently in sweet potato. Usually these mutations are minor, such as small patches of different skin colour on tubers, but even these minor mutations can gradually lead to a "mixed" clone if they are not detected and removed.

A few mutants may be better than their original clones, and you could evaluate them in the breeding trials.

Recurrent Selection

There are 3 steps in a recurrent-selection breeding programme:

1. Create a base population by selecting parent clones and intercrossing them in as many combinations as possible.

2. Grow, evaluate, and select the seedling-derived clones grown from seeds produced in the above step, and intercross selected clones in as many combinations as possible.

3. Include new germplasm in the crossing block when available (this is called "introgression").

In a recurrent-selection breeding programme, the first time you select and intercross parent clones you are creating what is called the base population or the original source population. It is important to begin with a wide genetic base. To do this, choose at least 20 parent clones that are unrelated and have a wide range of characters. To widen the genetic base, or to obtain specific characters not available in the local germplasm, it is often necessary to import seeds or vegetative material from other countries. However, this importation must be done in such a way that there is no risk of introducing new diseases and pests. Consult your local agriculture department before importing any plant material.

Seeds and PATHOGEN-TESTED (virus-indexed) plantlets growing as tissue cultures are safe ways to import materials if you follow recommended quarantine procedures. The first step in the importation process is to obtain an Import Permit from your Quarantine Division and then to cooperate fully with the requirements for phytosanitary certificates, post-entry quarantine, etc.

It takes about 2 years from Crossing Block until the harvest of the first Intermediate Trial. Therefore, if you plant a Crossing Block once each year, you will in fact have 2 recurrent-selection populations running at the same time.

How do you select seedling-derived clones for each cycle of intercrossing? You can base your selection on the phenotype of the seedling itself. However, when seedlings are planted in a Nursery Bed, you have only one plant of each growing in a situation that differs greatly from a farmer's field. Therefore, it is not possible to make accurate judgements on most characters at the seedling stage. After cloning the seedlings and evaluating the seedling-derived clones in the trial sequence, your judgement of their performance becomes increasingly accurate as you advance from Seedling Nursery through Hill Trial, Preliminary Trial, Intermediate Trials, Advanced Trials, and finally to Farmer Trials.

During the first 2 or 3 cycles of your recurrent-selection programme, apply only light selection pressure to allow maximum recombination to occur. For example, in the first cycle you could select and intercross all the seedling-derived clones that you select from the Hill Trial for planting in the Preliminary Trial. In the second and third cycles, you could select and intercross all the seedling-derived clones that you select from the Preliminary Trial for planting in the first Intermediate Trial.

After completing these early recombination cycles, you should increase the selection pressure. We do this by selecting and intercrossing all seedling-derived clones that we have selected from the first Intermediate Trial for advancement to the second Intermediate Trial (see Figure 1). We may also include in the crossing block a few clones from earlier trials that have good characters but are not good enough overall to be selected for further trial–for example, a clone that has a very high level of scab resistance but has poor tuber shape, or a clone with exceptionally high tuber number but with small tubers. In these later recombination cycles, use 30 or more parent clones.

Newly introduced germplasm can be used in the base population or introgressed (crossed) at any later time.

With each cycle of recurrent selection your breeding population will improve. This means that the frequency of desirable genes will increase, and your chances of finding clones with all the characters you want will increase.

If you have a clone with one or a few good characters but many undesirable characters, you can introgress it into your improved population without adding the genes for the undesirable characters to your improved population. Plant the clone to be introgressed in a border row of your crossing block. Use it as a female, but prevent its pollen from contaminating your improved population. To do this, you can either emasculate all flowers before they open and then permit them to open-pollinate, or you can clip all flowers closed and use them as females in hand pollinations. Remove any buds you do not plan to use as females before they open. Evaluate the progenies from these crosses in the trial sequence and repeat the procedure with the selections until they are improved enough for most characters to be included as normal parents in the recurrent-selection crossing block.

You can also base your selection on the breeding value of a seedling-derived clone, as judged by the performance of its progeny (progeny testing). This is often a better criterion than the phenotype of the seedling-derived clone. However, progeny testing adds a number of lenghty steps to the breeding programme and for this reason is usually not used in sweet potato breeding programs.

Genetics

The sweet potato is a polyploid with 6 sets of each chromosome (that is, a hexaploid), giving a total of 90 chromosomes. It is also heterozygous. Consequently the genetics of this crop are complicated, and segregation of characters always occurs in the offspring (progeny). Sweet potato has both qualitative and quantitative characters. Qualitative characters are distinct and discontinuous and are easily distinguished from each other. For example, stem colour is a qualitative character. Generally only 1 or 2 sets of genes control each qualitative character.

In contrast, quantitative characters are indistinct and continuous and gradually grade into each other, and usually many sets of genes are involved. For example, the shape and yield of tubers are quantitative characters.

For some characters, improvement through selection is rapid, but for other characters it is slow. This is determined by the heritability of the character. If a character has high heritability, the progeny will resemble the parents, and improvement through selection will be rapid.

Other characters have lower heritabilities such as yield, fibre content, tuber shape, tuber cracking, and number of tubers.

If a character has low heritability, improvement through selection will often be slow. It is sometimes possible to increase low heritabilities by increasing the number of replications in trials and using better screening techniques, such as artificial inocultation. Also, when heritabilities are low, it may be better to base your selection on progeny testing rather than on the parents.

It has been determined that flesh colour, flesh oxidation, % dry weight, % crude starch, % crude protein, skin colour, resistance to root-knot nematode, and vine length all have relatively high heritabilities.

Evaluating Specific Characters

Plant Type
Variability in plant type includes long vines compared to compact vines, few branches compared to many branches, vines that produce all tubers at the planting point compared to those that produce tubers both at the planting point and on the vines, and climbing vines compared to nonclimbing.

The ideal plant type or types for your location will depend on the needs of your farmers. Compact vines are often best for intercropping. Long, vigorous, many branched vines often compete best with weeds. Plants with many branches produce more planting material.

Subsistence farmers in some countries prefer vines that can be harvested over many months, because they produce tubers both at the planting point and on the vines. In contrast, commercial farmers usually prefer vines that produce tubers only at the planting point so they can be harvested all at one time. Most farmers do not like climbing vines, because they are very thin and make poor planting material.

Stem colour and leaf shape are usually not important to farmers.

OUR DATA SUGGEST THAT PLANT TYPE IS MATERNALLY INHERITED. This means that many of the offspring of a cross will have a plant type similar to the female parent. Therefore, when making crosses, use the clone with the best plant type as the female parent.

Stem Thickness
You can distinguish between THICK, MEDIUM, and THIN stems. Vines with thick stems produce strong cuttings, which establish well at planting. In comparison, thin-stem vines produce weak cuttings, which often die soon after planting. However, we have found that weevils damage thick stems more severely than thin stems. Therefore, we select clones with medium stems, since these establish well enough in the field but are not as susceptible to weevil damage as thick stems.

Our data suggest that stem thickness is also maternally inherited. Therefore, when making crosses, you should use the clone with the best stem thickness as the female parent.

Time from Planting to Harvest
To decide when to harvest your on-station trials, consider the needs of your farmers. Most commercial farmers prefer early cultivars that give high yields 4 or 5 months after planting. For many subsistence farmers, however, an early harvest is not as important as being able to harvest over a long period of time. For on-farm trials, the farmer should make the decision about when to harvest.

Disease, Insect, and Nematode Resistance

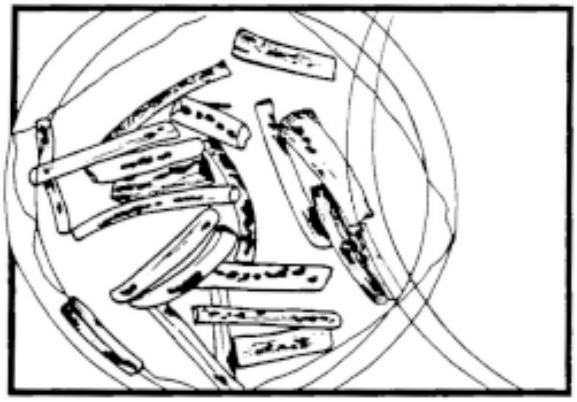
It is important that you develop a reliable rating scheme that can distinguish resistant from susceptible clones. Your rating scheme should have at least 3 classes, but it must not be so complex that it is difficult to use on a large number of clones in the field.

For evaluating leaf scab disease in the field, we use a scale of 0 to 4, with 0 meaning no plants in the clone showing symptoms of the disease, and 4 meaning all plants in the clone showing severe symptoms, and 1, 2 and 3 are of intermediate severity.

For little leaf disease and the various virus diseases, we have not yet found good sources of resistance, but we always discard those clones that have obvious symptoms of these diseases.

For evaluating weevils, we use a scale of HIGH, MEDIUM, and LOW, with High meaning that a high percentage of the tubers (more than 50%) are damaged by weevils and Low meaning that less than 10% of the tubers are weevil infested. Tuber placement affects weevil resistance, and therefore we prefer clones that have deep tubers and long "necks" attaching them to the stem base.

Most of our breeding clones, as well as all Tongan local cultivars, are susceptible to rose beetle, but we do note which breeding clones are less susceptible or more susceptible than average.



In Tonga we developed a method of artifical inoculation to evaluate seedlings for leaf scab resistance. Pieces of disease stems and petioles are incubated in petri dishes to produce inoculum (above). Seedlings are sprayed with inoculum and then placed in plastic bags to provide the high humidity necessary for disease development (below).

Yield

TOTAL YIELD of tubers is made up of EDIBLE YIELD plus REJECTS (nonedible including weevil damaged, rotten, and very small tubers). Edible yield is made up of tubers that are good enough to be sold (MARKETABLE YIELD) and tubers that can not be marketed but would be eaten by farm families. Which yields should you measure? If you are breeding new cultivars for subsistence farmers, edible yield is the most important. If you are breeding for commercial farmers, then marketable yield is the most important to measure. In Tonga, many farmers grow sweet potato to feed their families, but they also sell the extra tubers on the market. Therefore, we measure both edible and marketable yields. Total yield is usually not a very relevant measurement.

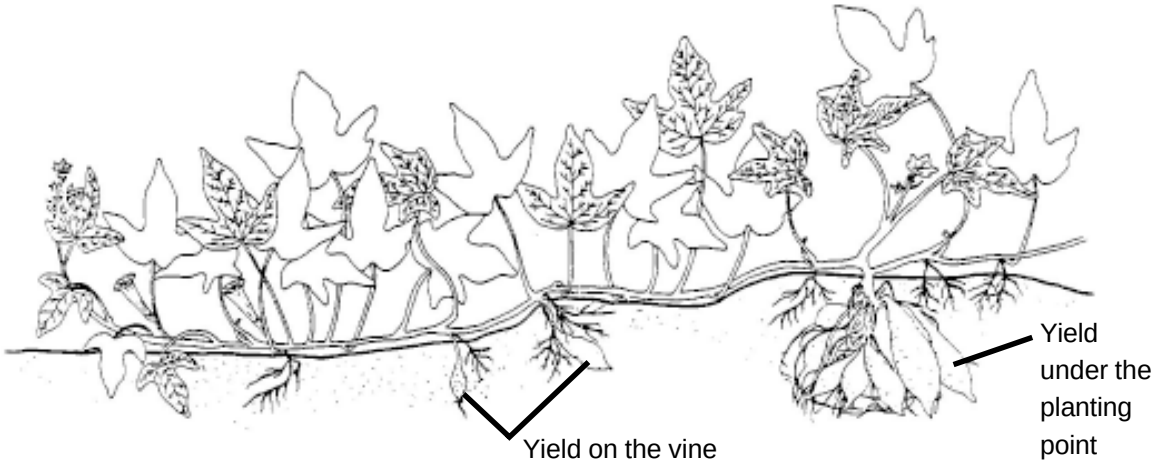
The yield of tubers harvested from under the planting point is easier to measure than the yield of tubers that grow on the vines. But if vine tubers are important to your farmers, then you must make the effort to measure this yield.

For all farmers, ability to produce high yields in the wet season is particularly important.

In Tonga our goal is to select clones that produce excellent yields in the dry season and at least reasonable yields in the wet season. This is why the Intermediate, Advanced and On-Farm Trials are each grown in a wet as well as a dry season.

Tuber yield is determined by a combination of TUBER NUMBER and TUBER WEIGHT. Clones that produce large numbers of medium-sized tubers and clones that produce medium numbers of large tubers may have the same yields but may not be equally acceptable to farmers. Farmers in the Pacific Islands often prefer large tubers, even if the yield is somewhat lower.

In Tonga, sweet potato plays an important role in feasting and presentations and extra large tubers are needed for these ceremonial occasions. This may also be true in your location. We therefore note during harvest those breeding clones that can be used only for eating and marketing and those that produce enough extra-large tubers for ceremonial use. It is not necessary for all new cultivars released from a breeding programme to be appropriate for ceremonial use, but at least a few should be.



Tuber Characters

Is there a preference for a certain **tuber shape** in your location? If there is, then you should select breeding clones with that shape. We classify tuber shape as ROUND, ELONGATEROUND (oval), and ELONGATE.

Smoothness indicates how easy or difficult it is to wash and peel the tubers. We use the categories SMOOTH, MEDIUM, and ROUGH.

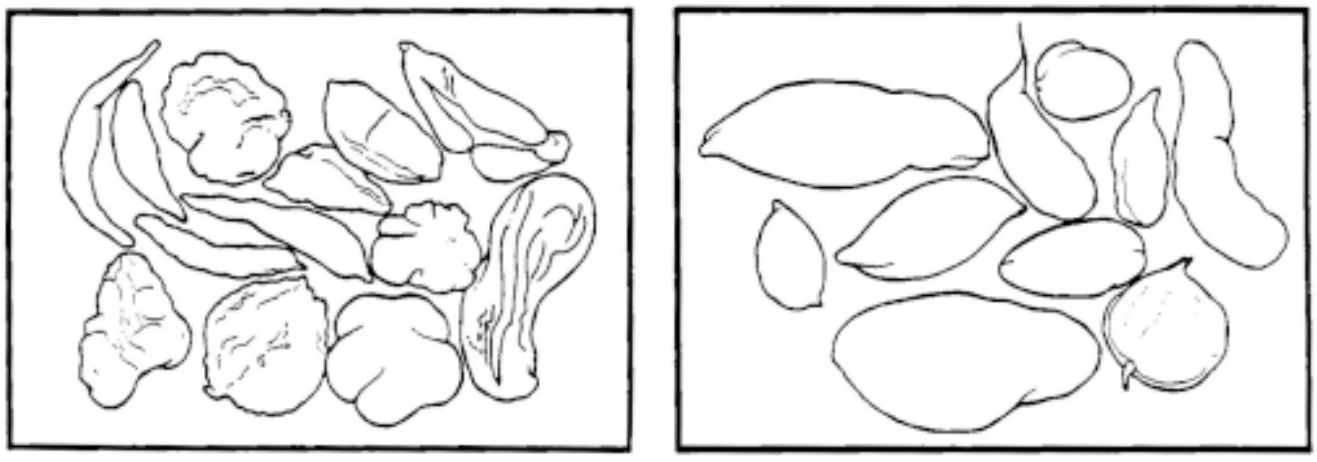
Cracked tubers are unattractive and difficult to wash and peel. One type of cracking is also a symptom of root-knot nematode attack. Therefore, you should discard breeding clones that have a high percentage of cracked tubers at harvest. For cracking, we use the ratings MANY, FEW, NONE.

Another undesirable character is **precocious tuber sprouting**, which means that tubers sprout before harvest time. We rate precocious sprouting as ABSENT or PRESENT.

Farmers and consumers may have a strong preference for certain **tuber skin and flesh colours**, or they may accept many different colours. Be certain that you understand the situation in your location before you begin your breeding programme.

Note that tubers with orange and bright yellow flesh are higher in vitamin A than tubers with other flesh colours, but they are also sweet tasting and moist, with low percent dry weight. Therefore, they are often not preferred by Pacific Islanders.

Tubers that are damaged by rats or weevils will often sprout. Therefore, evaluate precocious sprouting only on undamaged tubers.



In breeding populatins, tuber characters are very variable. The tubers on the left are undesirable because they have poor shapes, many cracks, and/or are rough. In contrast, the tubers on the right have good shapes, few or no cracks, and are smooth.

Eating Quality

Generally, Pacific Islanders prefer hard, dry, low-sugar sweet potatoes. Therefore, *percent dry weight* is a good measure of eating quality. In Tonga for example, cultivars having dry weights of 30% or higher are preferred to those with dry weights of 25 to 28%.

We measure percent dry weight of all clones in Advanced Trials. To do this, we select 5 marketable tubers of each cultivar from each replication. We treat each tuber as a separate sample. We scrub it in water with coconut husk or an other abrasive material, cut off the ends as for cooking, chop the rest of the tuber into cubes 1 cm square or smaller, and place it into a paper bag or small aluminum foil baking pan. We then weigh each sample to determine its fresh weight, dry it in a laboratory oven at 100°C until it has reached constant weight (that is, when further drying does not lower the weight), and finally weigh it again to determine dry weight.

You calculate percent dry weight as:

$$\% \text{ dry weight} = \frac{\text{dry weight}}{\text{fresh weight}} \times 100$$

Do not forget to "tare" (deduct) the weight of the paper bag or baking pan when you weigh fresh and dry samples. And when the relative humidity is high, you must weigh dry samples IMMEDIATELY after removing them from the oven because they quickly absorb moisture from the air and gain weight.

Often there is not enough oven space and labour to determine percent dry weight of the large number of breeding clones in Intermediate, Preliminary, and Hill Trials. When this occurs, *specific gravity* can be used to estimate dry weight and eating quality

We estimate specific gravity by determining whether a tuber sinks or floats in a solution of common table salt dissolved in water. For Intermediate Trials we select 5 marketable tubers of each clone from each replication. For the unreplicated Preliminary and Hill Trials we select 5 marketable tubers of each clone that has performed well for all other characters.

To estimate specific gravity, make up 1 bucket for each specific gravity rating by adding a specific amount of salt to 6 litres of water (see Table 2). Treat each tuber as a separate sample. Wash it in water. (Unlike dry weights, it is not necessary to scrub off the skin.) Then place it in Bucket 0. If it sinks, move it to Bucket 0.5, then Bucket 1.0, then Bucket 2.0, etc, until the tuber floats to the surface of the salt solution. Give the sample the specific gravity rating of the bucket in which it first floats, and then average the ratings of the 5 tubers to obtain a mean rating for the replication (Intermediate Trials) or clone (Preliminary and Hill Trials).

Clones that Tongans usually consider "excellent eating quality" have specific gravity ratings of 3 or higher, and clones they consider "poor eating quality" have specific gravity ratings of 1 or lower.

Table 2. How to prepare a series of salt solutions to estimate the specific gravity of sweet potato tubers.

Specific Gravity rating	Amount of salt (grams) to dissolve in 6 liters of water	Actual Specific Gravity
0	0	1.0000
0.5	150	1.0173
1	300	1.0347
2	600	1.0680
3	900	1.1002
4	1200	1.1316

To save time when measuring specific gravity of large numbers of clones in Hill Trials, we use only one bucket of salt solution, with the lowest acceptable specific gravity rating for that season, usually Bucket 1. If 3 or more of the 5 tubers from a clone float in this salt solution, we discard the clone.

Of course, the best method to determine the eating quality of breeding clones is to evaluate them in taste tests. However, taste tests are time consuming and only a few clones can be accurately "tasted" at any one time. Therefore, taste tests must usually be delayed until Advanced and On-Farm Trials.

There are several methods of conducting taste tests, some of them very complicated. However, we have found that a relatively simple test is accurate enough. From each replication of Advanced Trials, we select 2 average tubers of each breeding clone and each check cultivar. We cook these in the "umu", since this is the most common method of cooking sweet potato in Tonga. Prepare your tubers using the most common cooking method in your location. We then peel the cooked tubers, cut them into small pieces, and put each clone on a separate plate that has been labelled with a code number (not the actual number that some tasters might recognize). We invite at least 20 Tongans to taste several pieces from each plate and fill out an evaluation form. On this form we ask them to rate each clone as 4 (very good, I like it very much), 3 (good), 2 (OK), or 1 (poor, I do not like it). We also ask them to write remarks about each one, explaining why they do or do not like it.

Tongan taste-testers make negative remarks like "too sweet", "soft", "stringy", "sour" and positive remarks like "good taste", "firm", "attractive colour".

Of course, taste is not the only factor that determines the ratings that our tasters give to a sample. They are also influenced by how the sample looks (colour, crumbling), its texture, and the presence of fibres. All these factors are important in determining eating quality.

Be sure that you use "heat-proof" labels to identify different clones during cooking. Metal labels are best, and some marking pens will last through the "umu". For boiling, you can cut the tubers into different shapes for identification.

Nutritional Value

Protein content, protein-inhibitor content, and vitamin content are very important nutritional factors that should be evaluated in your sweet potato breeding programme. However, most breeding programmes cannot afford the expensive equipment and highly trained technicians required to measure these nutritional factors. If possible, you should establish a collaborative project with an overseas institution where you can send samples of clones from Advanced Trials for analysis.

Vitamin A is the only nutritional factor that is easy to determine. It is related to flesh colour, and clones with orange and bright yellow flesh have high Vitamin A content.

SUPPLIES

Pollinating Clips
778C O.K. Fasteners, 10 mm, 13/32 in., No. 1-B, 100 in a box; from Labelon Corporation, Canandaigua, New York 14424, USA.

Merchandise Tags for labeling pollinations
Standard quality, white, 1-15/16 x 1-1/4 in., No. 6, No. 12-203, 1000 in a box; from Denney-Reyburn Company, West Chester, Pennsylvania 19380, USA.

Whit e Plastic Labels for marking baskets
Diamond-Lox, white, 5-1/2 x 1/2 in., 1000 in a box; from A.M. Leonard, Inc., P.O. Box 816, Piqua, Ohio 45356-0816, USA.

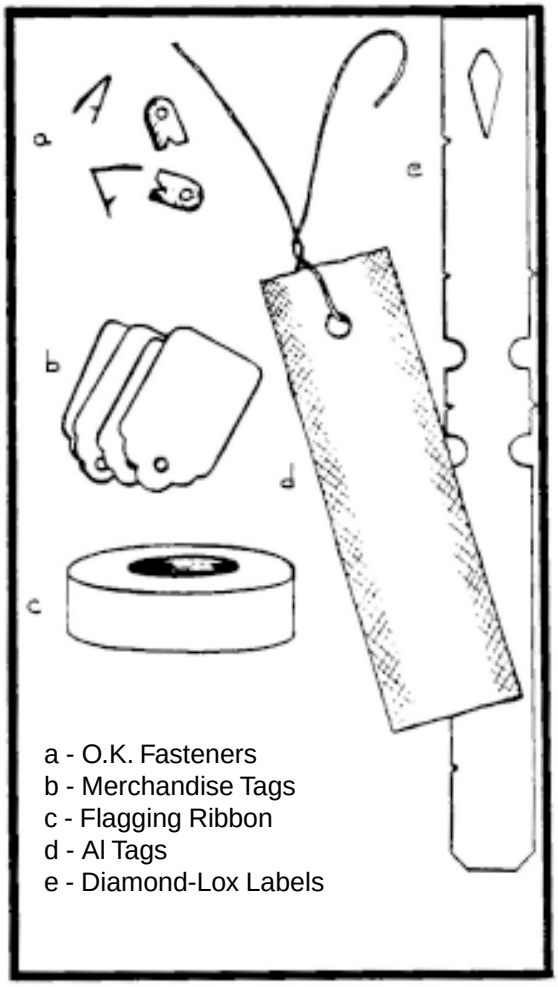
Flagging Ribbon for marking
Flagging, polyethelene or vinyl, 1-3/16 in. wide, many colours, 100 yds/roll; from Forestry Suppliers, Inc., 205 West Rankin St., P.O. Box 8397 Jackson Mississippi 39204-0397, USA.

Aluminum Labels for marking field stakes
Al Tags, 3/4 x 3 in., 9 in. wire, can be permanently embossed with pen or pencil, 1000 in a box; from Forestry Suppliers, Inc., 205 West Rankin St., P.O. Box 8397 Jackson Mississippi 39204-0397, USA.

Field Record Books
Lietz Level Book, No. 8152-55, 4-1/2 x 7-1/4 in., water repellent; from Forestry Suppliers, Inc. 205 West Rankin St., P.O. Box 8397 Jackson Mississippi 39204-0397, USA.

Plastic Net Bags for cuttings and small lots of tubers
Sold for packaging onions, potatoes, etc., available in rolls of long tubes that can be cut to any length, and in many bright colours.

Nursery Marking Pens
Permanent, sunproof, waterproof, fine point, Number UH0960; from The John Henry Company, 5800 W. Grand River, P.O. Box 17099, Lansing, Michigan 48901-7099, USA.



a - O.K. Fasteners
b - Merchandise Tags
c - Flagging Ribbon
d - Al Tags
e - Diamond-Lox Labels